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Indian Standard

SPECIFICATION FOR HIGH-VOLTAGE FUSES FOR EXTERNAL PROTECTION OF SHUNT POWER CAPACITORS

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Indian Standard

SPECIFICATION FOR HIGH-VOLTAGE FUSES FOR EXTERNAL PROTECTION OF SHUNT POWER CAPACITORS

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Indian Standard
SPECIFICATION FOR HIGH-VOLTAGE FUSES FOR EXTERNAL PROTECTION OF SHUNT POWER CAPACITORS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 16 January 1980, after the draft finalized by the High Voltage Switchgear and Controlgear Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The object of this standard is to formulate uniform requirements and test procedures regarding performance and testing of fuses intended to be used for capacitor protection.

0.3 Three classes of high voltage fuses are in general use, the expulsion, the liquid and the high rupturing capacity cartridge types. The most common application is on distribution systems up to 33 kV, while the liquid and cartridge type fuses are available for use on systems up to 132 kV and used largely for protecting voltage transformers.

0.4 The general requirements and tests for and guidelines for application of high voltage fuses of all types are covered in various parts of IS : 9358*. Fuses intended for use in capacitor protection have to comply with special performance requirements specified in this standard.

0.5 In the preparation of this standard, considerable assistance has been derived from IEC Pub : 549 (1976) ' High voltage fuses for the external protection of shunt power capacitors ', issued by the International Electrotechnical Commission.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Specification for high voltage fuses:

Part I	Current limiting fuses.
Part II	Expulsion and similar fuses.
Part III	Application guide for high voltage fuses (*under preparation*).

†Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard applies to external fuses used with high-voltage power capacitors (conforming to IS : 2834-1964*) for use on alternating current systems of 50 Hz.

1.2 Fuses according to this standard are intended to clear either faults inside a capacitor unit to permit continued operation of the remaining parts of the bank in which the unit is connected (unit fuses) or faults on the whole capacitor bank to isolate the bank from the system (line fuses).

1.3 These fuses are not a substitute for a mechanical switching device, but when forming a part of a mechanical switching device such as a fuse-switch or a fuse-disconnector, they shall comply with this standard.

1.4 When fuses are used for the external protection of a capacitor unit or a capacitor bank (line fuses), their voltages and breaking ratings shall be adequate for the system.

1.5 Fuses according to this standard shall comply with the requirements of IS : 9385 (Part I)-1979† and IS : 9385 (Part II)-1979† except those which are specifically excluded by this standard.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions covered by IS : 1885 (Part XVII)-1979‡ and the following shall apply.

2.1 Capacitor Element (or Element) — An indivisible part of a capacitor consisting of electrodes separated by a dielectric.

NOTE — The word 'element' in this standard is used according to the definition of IS : 2834-1964*.

2.2 Capacitor Unit (or Unit) — An assembly of one or more capacitor elements in a single container with terminals brought out.

2.3 Capacitor Bank (or Bank) — A group of units, connected electrically to each other, for example, a three-phase bank may be composed of three single-phase units.

2.4 Capacitor — In this standard, the word 'capacitor' is used when it is not necessary to lay particular stress upon the different meanings of the word 'capacitor unit' or 'capacitor bank'.

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*Specification for shunt capacitors for power systems.

†Specification for high voltage fuses:

Part I Current limiting fuses.

Part II Expulsion and similar fuses.

‡Electrotechnical vocabulary : Part XVII Switchgear and controlgear (*first revision*).

2.5 Capacitor Equipment — An assembly of capacitor units and accessories suitable for connection to a circuit.

2.6 Bank Protection — Common name for all protective equipment, except the internal fuses, for a capacitor bank or part thereof.

2.7 Unbalance Protection — A device sensitive to capacitance difference between branches of the bank normally in balance with each other.

NOTE — The capacitance difference may be due to blown fuses or insulation failure within the bank.

2.8 Unit Fuse — Fuse intended to be used for the protection of a capacitor unit which forms a part of a capacitor bank.

2.9 Line Fuse — Fuse intended to be used for the overall protection of a capacitor connected to a given point of a system.

2.10 Refill Unit — A set of replacement parts sufficient to restore a fuse-link to its original condition after an operation.

2.11 Capacitive Breaking Current — A current for which the specified conditions of use and behaviour include the opening of the circuit of a capacitor unit or capacitor bank.

2.12 Rated Capacitive Breaking Current — The maximum capacitive breaking current that the fuse shall be capable of breaking under the conditions of use and behaviour prescribed in this standard.

3. PERFORMANCE REQUIREMENTS

3.1 General — The fuse is connected in series with the unit(s) which the fuse is intended to isolate if the unit(s) becomes faulty. The range in currents and voltages for the fuse is, therefore, dependent on the characteristics of the capacitor and the bank in which the fuse is connected as well as the parameters of the supply circuit.

3.1.1 The operation of an external fuse is in general determined by the following two factors:

a) The power-frequency fault current resulting from either a partial or complete capacitor failure, and

b) The discharge energy from any units in parallel with the fault.

3.1.2 However, this standard gives a method of separate checking of these factors.

3.1.3 These requirements are valid for capacitors switched by a restrike-free switching device. If the switching device is not restrike-free, other requirements are to be agreed upon.

3.1.4 As used in this standard, U_n is the rated voltage of the capacitor unit and U_{nf} is the rated voltage of the capacitor fuse.

3.2 Breaking Requirements

3.2.1 *Operating Voltages* — The fuse shall be so selected as to isolate the faulty unit(s) with a minimum disturbance to the system and to the capacitor unit involved under maximum prevailing system conditions occurring at the time of the fault and at the following voltages:

a) Under transient current conditions, for example during energization the higher limit of the transient voltage between terminals of the unit is $2{\cdot}0\ U_n \sqrt{2},$ where U_n is the rated voltage of the unit. After operation, the fuse shall be capable of withstanding the above transient voltage.

NOTE — The fuse manufacturer shall specify if the fuse capability differs from the above requirements.

b) When the fuse is subjected to power-frequency capacitive currents, it shall be capable of operating against a voltage of $1{\cdot}1\ U_n$ and then withstanding this voltage plus any dc voltage component resulting from any capacitive charge remaining after the operation of the fuse.

3.2.2 *Rated Capacitive Breaking Current* — For current-limiting fuses, the preferred values of the rated capacitive breaking current are 20 and 50 times the rated current of the highest current rating of a homogeneous series, as defined in IS : 9385 (Part I)-1979*. Other values shall be the subject of an agreement between the manufacturer and the user.

For expulsion fuses, the preferred values of the rated capacitive breaking current are 20 and 50 times the rated current of the largest refill unit recommended by the manufacturer of renewable fuse-links. Other values shall be the subject of an agreement between the manufacturer and the user.

3.3 Withstand Requirements

3.3.1 *Rated Voltage* — The rated voltage U_{nf} of the fuse shall not be less than 1·1 times the rated voltage U_n of the capacitor unit.

3.3.2 *Rated Current* — The rated current of the fuse shall be at least 1·43 times the rated current I_n of the capacitor.

NOTE 1 — In principle, the continuous current does not exceed 1.3 times I_n, but as the capacitance may reach 1·1 times the value corresponding to the rated output, the current may have a maximum value of $1{\cdot}3 \times 1{\cdot}1 = 1{\cdot}43$ times the rated current.

NOTE 2 — When the air temperature at the fuse location exceeds 40°C, it is recommended to consult the manufacturer.

NOTE 3 — For certain types of fuse-links having an overload capability, it is recommended to take this property into consideration.

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*Specification for high voltage fuses: Part I Current limiting fuses.

4. TYPE TESTS

4.1 General — To comply with this standard, fuses shall be subjected to the tests specified in Table 1.

NOTE — For fuses belonging to a homogeneous series as defined in IS : 9385 (Part I)-1979* and IS : 9385 (Part II)-1980* it is allowed that tests made on a reduced number of current ratings shall be valid for other current ratings.

TABLE 1 TESTS FOR DIFFERENT TYPES OF FUSES

(*Clauses* 4.1, 4.2.1.4 *and* 5.1)

TESTS	FUSES TO BE USED WHERE INDUCTIVE CURRENTS CAN FLOW (*see* NOTE 2)		FUSES TO BE USED WHERE INDUCTIVE CURRENTS ARE NOT LIKELY TO FLOW (*see* NOTE 3)
	Line Fuses	Unit Fuses	
(1)	(2)	(3)	(4)
Inductive currents (*see* Note 1)	×	×	—
Capacitive currents (*see* **4.2**)	*see* Note 4	×	×
Discharge (*see* **4.3**)	×	×	×

NOTE 1 — These tests shall comprise the following:

Test duties 1 and 2 according to IS : 9385 (Part I)-1979* or test duties 1, 2 and 3 according to IS : 9385 (Part II)-1980*

NOTE 2 — Examples of such applications are:

a) line fuses,

b) unit fuses in delta-connected banks without units in series, and

c) unit fuses in star-connected banks without units in series and with earthed neutral.

NOTE 3 — Examples of such applications are:

a) unit fuses in star-connected banks with unearthed neutral, and

b) banks where units are used in series.

NOTE 4 — For use with unearthed star-connected banks, line fuses shall be tested on capacitive currents.

*Specification for high voltage fuses:

Part I Current limiting fuses.

Part II Expulsion and similar fuses.

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*Specification for high voltage fuses:

Part I Current limiting fuses

Part II Expulsion and similar fuses (*first revision*)

4.1.1 *Test Practices*

4.1.1.1 The fuse shall be new, clean and in good condition.

4.1.1.2 The fuse-link shall be tested in a fuse-base as specified by the manufacturer of the fuse-link.

4.1.1.3 In making tests of a test duty within a series of renewable fuse-links, only the fuse-elements, refill units and parts normally replaceable shall be replaced. A new fuse-carrier shall be used for tests of the other test duty.

4.2 Capacitive Breaking Current Tests — For both current-limiting fuses and expulsion fuses belonging to a homogeneous series as defined in IS : 9385 (Part I)-1979* and IS : 9385 (Part II)-1980* tests shall be made on the fuse-links with the highest current rating.

4.2.1 *Description of Tests to be Made*

4.2.1.1 These tests are intended to prove the ability of the fuse to break capacitive currents and shall include two test duties.

Test duty A: Verification of the rated capacitive breaking capacity (*see* **3**).

Test duty B: Verification of the operation with a current value resulting in a pre-arcing time of (5 ± 2) minutes.

4.2.1.2 The test circuits specified in **4.2.2** and the parameters specified in **4.2.5** have been so chosen as to reproduce as closely as possible the duty which the fuses experience in actual applications.

4.2.1.3 When applied as unit fuses, the mode of failure of the capacitor units determines the magnitude of the current which the fuse must break.

4.2.1.4 For the complete failure of a capacitor unit, the bank configuration determines the magnitude and characteristics (inductive or capacitive) (*see* Table 1) of the current through the unit and its fuse. Test duty A simulates the condition where the fuse breaks capacitive current.

4.2.1.5 For progressive element failure in the capacitor unit, the current increases until it reaches a magnitude that will just melt the fuse. Test duty B simulates this condition.

4.2.2 *Test Circuits* — The tests shall be made with single-phase alternating current and with single fuse. The supply circuit shall have an impedance such that the voltage variation caused by switching the capacitive current shall not exceed 10 percent. The power factor of the supply circuit shall not exceed 0·15 lagging and its capacitance shall be as low as possible.

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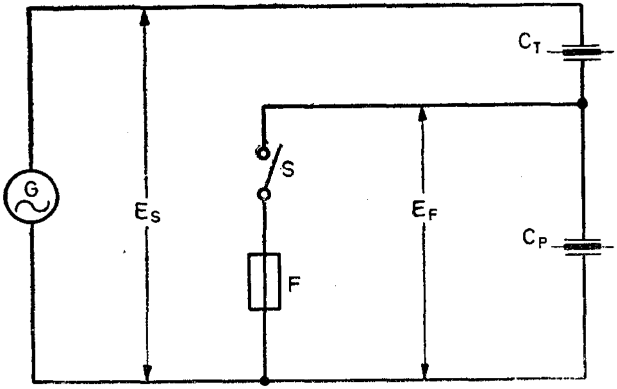
*Specification for high voltage fuses:

Part I Current limiting fuses.

Part II Expulsion and similar fuses.

4.2.2.1 For test duty A on unit fuses, the load circuit shall be as shown in Fig. 1.

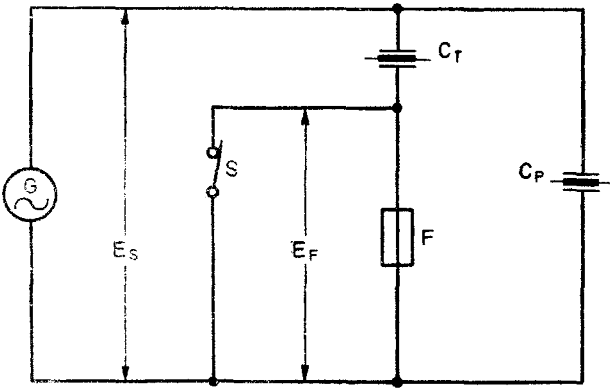


G = Generator
E_S = Source Voltage
E_F = Recovery Voltage
F = Fuse
S = Switch
C_T = Capacitors to Produce the Test Current
C_P = Capacitors Corresponding to the Capacitors in Parallel with the Failed Unit

FIG. 1 TEST CIRCUIT FOR TEST DUTY A

Operation of the fuse is initiated by closing the switch S in series with the fuse, in order to simulate the total failure of a capacitor unit protected by the fuse. C_T represents the capacitance in the bank which limits the fault current and C_P represents the capacitors which are in parallel with the failed unit. The value C_P in microfarads shall be $C_P \geqslant \frac{1\,000}{U^2_{nf}}$, U_{nf} being expressed in kilovolts.

The source voltage E_s should be so chosen that, taking into account the ratio of the capacitances $\frac{C_T}{C_P}$, the specified power-frequency recovery voltage given in Table 2 is obtained. It is expected that, in the light of some further empirical evidence, a more precise relationship between E_s and E_f may be evolved.



G = Generator
E_S = Source Voltage
E_F = Recovery Voltage
F = Fuse
S = Switch
C_T = Capacitors to Produce the Test Current
C_P = Capacitors Corresponding to the Capacitors in Parallel with the Failed Unit

FIG. 2 TEST CIRCUIT FOR TEST DUTY B

4.2.2.2 For test duty B on unit fuses, the load circuit shall be as shown in Fig. 2. Operation of the fuse is initiated by opening the switch S in parallel with the fuse. C_T represents the remaining healthy elements of the capacitor units and C_P represents the other units in the bank which are in parallel with the failed unit. The value of C_P in microfarads shall be $C_P \geqslant \frac{1\,000}{U^2_{nf}}$, U_{nf} being expressed in kilovolts.

NOTE — In both circuits, the effect of capacitance on the recovery voltage appearing across the fuse when it operates is taken into account by C_P. The minimum value specified represents between 300 kvar and 400 kvar (depending on frequency), that is, the size of the smallest capacitor bank on which individual fuses would normally be applied. Experience has shown that the value of C_P is not critical in its effect on the capacitive current-breaking performance of fuses, and therefore only a minimum value is specified.

4.2.2.3 For test duties A and B on line fuses, the load circuit shall be as shown in Fig. 1, except that capacitance C_P shall be omitted.

The waveform of the current to be broken should, as nearly as possible be sinusoidal. This condition is considered to be complied with if the ratio of the rms value of the current to the rms value of the fundamental component does not exceed 1·2.

The current to be broken shall not pass through zero more than once per half-cycle.

4.2.3 *Arrangement of the Equipment* — Expulsion and current-limiting fuses which automatically provide an isolating gap after operation shall be mounted as they will be in a capacitor bank. An energized fuse shall be placed on each side of the fuse under test to determine adequately that any expulsion of gas or reduction of clearance does not cause flashover which might initiate operation of the adjacent fuses. Other current-limiting fuses may be mounted in any convenient manner.

4.2.4 *Test Procedure*

The test procedure to obtain the specified prospective current shall be that specified for the breaking tests in IS : 9385 (Part I)-1979* and IS : 9385 (Part II)-1980*.

4.2.5 *Parameters to be Used for Tests*

4.2.5.1 The parameters to be used when making the tests are given in Table 2.

TABLE 2 PARAMETERS USED FOR MAKING TESTS

(*Clauses* 4.2.2.1 *and* 4.2.5.1)

PARAMETERS (1)	TEST DUTY A (2)	TEST DUTY B (3)
Power-frequency recovery voltage (that is excluding dc voltage component)	$1{\cdot}0\ U_{nf}\ {}^{+5}_{\ 0}$ percent	$1{\cdot}0\ U_{nf}\ {}^{+5}_{\ 0}$ percent
Power factor (leading)	$\leqslant 0{\cdot}15$	$\leqslant 0{\cdot}15$
Prospective current	Rated capacitive breaking current	Current value resulting in a pre-arcing time of (5 ± 2) minutes
Making angle after voltage zero	From 0° to 20°*	Random timing
Number of tests	3	2

*This produces the most severe condition for the fuse since closing the circuit near voltage zero minimizes discharge current from the parallel capacitance and its effect on the pre-arcing time of the fuse.

4.2.5.2 For expulsion fuses and current-limiting fuses which automatically provide an isolating gap after operation, the voltage shall be maintained on the fuse for 1 second. For other current limiting fuses, the time shall be 60 seconds.

---

*Specification for high voltage fuses:

Part I Current limiting fuses.

Part II Expulsion and similar fuses.

4.3 Discharge Tests — These tests are made to verify:

a) the I^2t to which the fuse-link can be subjected for repetitive discharges (endurance discharge tests), and

b) the energy which the fuse can withstand without bursting (breaking discharge tests).

A calibration test shall be made by replacing the fuse-link under test by a link of negligible impedance compared with that of the test circuit. This test may be made with a reduced voltage.

The circuit shall be adjusted to give the specified discharge I^2t or energy, oscillatory frequency and decrement. This shall be verified by an oscillographic record. The ratio between successive peaks shall be from 0·8 to 0·95 for the endurance discharge tests and from 0·8 to 0·95 for the breaking discharge tests.

Tests shall be made on new fuses with the amount to I^2t and energy specified by the manufacturer (*see* **5**).

4.3.1 *Endurance Discharge Tests* — For both current-limiting fuses and expulsion fuses belonging to a homogeneous series as defined in IS : 9385 (Part I)-1979* and IS : 9385 (Part II)-1980*, tests shall be made on the fuse-links with the highest and the lowest current ratings.

4.3.1.1 These tests may be made at any convenient voltage and shall include two test duties:

a) 5 discharges on the same fuse-link within 10 minutes.

The discharge oscillatory frequency shall be:

f (kHz = 1·2 U_{nf} (kV) $^{+20}_{0}$ percent for fuse-links with rated current not exceeding 31·5 A.

f (kHz) = 0·8 U_{nf} (kV) $^{+20}_{0}$ percent for fuse-links with rated current exceeding 31·5 A.

b) 100 discharges on the same fuse-link at a time interval set by the manufacturer.

4.3.1.2 The discharge oscillatory frequency shall be 8 kHz $^{+20}_{0}$ percent. The value of I^2t shall be estimated from the oscillogram of current or by an equivalent method.

After this test, the fuse-link shall be still conducting.

4.3.2 *Breaking Discharge Tests* — For current-limiting fuses belonging to a homogeneous series as defined in IS : 9385 (Part I)-1979*, tests shall be made on the fuse-link with the highest current rating.

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*Specification for high voltage fuses:

Part I Current limiting fuses.
Part II Expulsion and similar fuses.

For expulsion fuses belonging to a homogeneous series as defined in IS : 9385 (Part II)-1980*, tests shall be made on the fuse-link rating with the largest distance between arcing terminals. If there are a number of fuse-links with the same distance, tests shall be on the one having the lowest current rating.

4.3.2.1 *Test Circuit* — Tests shall be made with a capacitor the capacitance of which is such that the stored energy has the specified value at the test voltage specified below. This capacitor shall be charged by means of dc to one of the following voltages:

a) $1{\cdot}82\ U_{nf}\ \sqrt{2}$ for current-limiting fuses, and

b) $1{\cdot}10\ U_{nf}\ \sqrt{2}$ for expulsion fuses unless otherwise specified.

The capacitor shall be discharged through the fuse under test in a circuit in which the oscillatory frequency is:

$f\,(\text{kHz}) = 1{\cdot}2\ U_{nf}\ (\text{kV})\ {}^{+20}_{\ \ 0}$ percent for fuse-links with rated currents not exceeding 31·5 A.

$f\,(\text{kHz}) = 0{\cdot}8\ U_{nf}\ (\text{kV})\ {}^{+20}_{\ \ 0}$ percent for fuse-links with rated currents exceeding 31·5 A.

4.3.2.2 *Test Procedure* — Two tests shall be made. For expulsion fuses, the second test shall be made on a completely new fuse. For fuses that do not introduce a visible air gap in the circuit upon operation, the voltage shall be maintained on the fuse for 10 minutes after operation. This requires the capacitor used for the test to be without discharge resistance.

For other fuses, no requirements concerning the maintained voltage are specified. For current-limiting fuses, the residual voltage across the capacitor shall be measured immediately after the discharge to determine the amount of energy dissipated in the fuse-link. The residual voltage shall be recorded in the test report.

4.3.2.3 *Standard conditions of behaviour with respect to breaking tests*

a) Flashover to earth or to adjacent capacitor units shall not occur during operation when mounted in accordance with the recommendations of the manufacturer.

   A current-limiting fuse-link shall not emit flame or powder; although a minor emission of flame from a striker or indicating device is permissible provided this does not cause breakdown or significant leakage current to earth.

b) After the fuse has operated, the components of the fuse, apart from those intended to be replaced after each operation, shall be in substantially the same condition as at the beginning of the test except for the erosion of the bore of the fuse tube of expulsion fuses.

---

*Specification for high voltage fuses: Part II Expulsion and similar fuses.

For current-limiting fuses, it shall be possible to remove the fuse-link in one piece after the operation.

However, after the discharge breaking test, the components of the fuse may be damaged and require replacement to restore the fuse to operating condition.

c) After operation, the fuse shall be capable of withstanding the voltages specified in **3.2.1** (a) across its terminals. When a fuse which automatically provides an isolating gap after operation has operated, it must also provide the specified dielectric properties.

5. INFORMATION TO BE GIVEN TO THE USER

5.1 The following information shall be given to the user:

a) Rated voltage of the fuse;

b) Current rating of the fuse-link or refill unit; in addition, the maximum continuous current capability may also be specified;

c) Current rating of the fuse-base or fuse-carrier contacts;

d) Time-current characteristics as specified in IS : 9385 (Part I) 1979* and IS : 9385 (Part II)-1980* for an ambient air temperature of 27°C;

NOTE 1 — Information shall be available on request concerning ambient air temperature in the range $-40°C$ to $+75°C$.

NOTE 2 — If tolerances on the current closer than ± 20 percent are required, they shall be specified on request.

e) Rated capacitive breaking current, where appropriate (*see* Table 1);

f) Rated inductive breaking current, where appropriate (*see* Table 1);

g) Maximum I^2t values which the fuse can withstand for 5 and 100 discharge;

h) Maximum available capacitor energy which the fuse can withstand at the voltage specified in **4.3.2.1** without bursting (unless otherwise specified, 40 kJ for current-limiting fuses);

j) Minimum pre-arching I^2t (under substantially adiabatic conditions) and maximum total clearing I^2t at inductive and capacitive power-frequency currents;

k) Cold resistance of fuse-link and percentage tolerance of resistance value; and

l) External creepage distance along the fuse-link (for other than fuses which automatically provide an isolating gap after operation).

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*Specification for high voltage fuses:

Part I Current limiting fuses.

Part II Expulsion and similar fuses.